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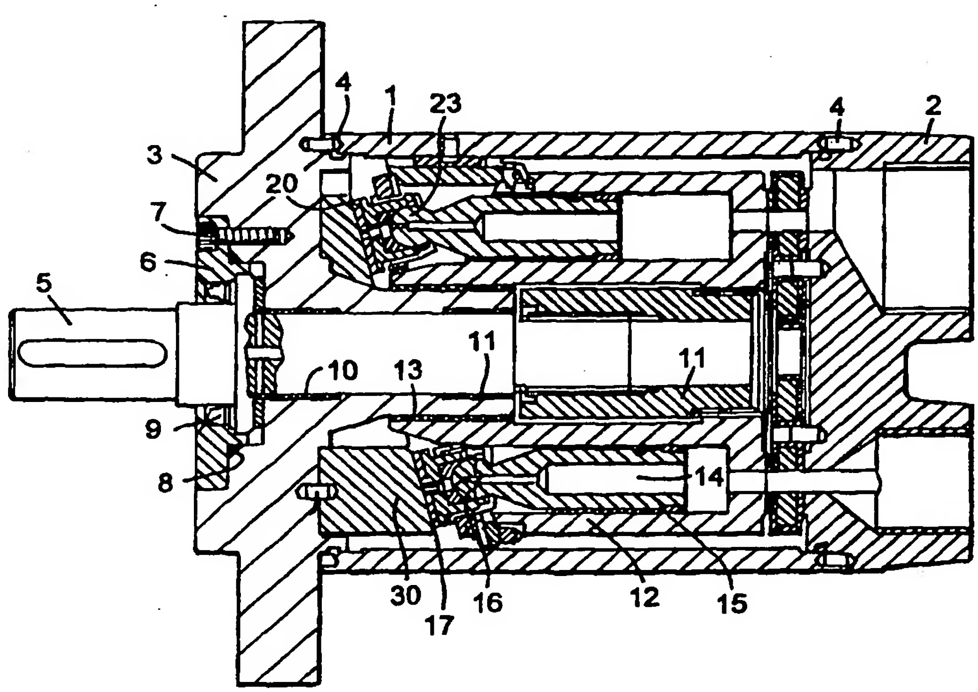

(57) Abstract

A piston assembly for an axial displacement pump or motor comprises a piston (15) having at one end a ball shaped piston foot (16) and a slipper (41). The rear end of which defines a piston ball seat (42) in which the ball shaped piston foot (16) is received. A slipper pad (44) defines an annular, centrally located recess or pocket at the front end of the slipper (41). The slipper pad (44) comprises an annular ring (44) of polymer material.

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DESCRIPTION

'IMPROVEMENTS IN AND RELATING TO HYDRAULIC PUMPS AND MOTORS'

The present invention relates to hydraulic pumps and motors, and more especially to an improved slipper design for use therein.

A known hydraulic pump comprises an outer casing, a cylindrical block keyed to a drive shaft and a plurality of piston assemblies each mounted within a respective axially extending bore in the cylinder block. Each piston assembly comprises a hollow piston which is slidable back and forth within its bore and a slipper which is mounted on a ball joint at the end of the piston. The slippers are supported against an angled swash plate which is fixed in position relative to the rotatable cylinder block.

At the other end of the cylinder block from the angled swash plate there is provided a port plate which is fixed in position relative to the rotatable cylinder block. The port plate has in it an inlet port through which water is supplied to the piston bores in the cylinder block and an outlet port through which water is expelled from piston bores under pressure. The exact mode of operation of such a pump will now be described.

In use, the cylinder block is rotatably driven by means of a prime mover connected to the drive shaft. As each piston bore passes into alignment with the inlet port in the port plate water is drawn into the bore, as the piston is moved

along the length of the bore by the action of the slipper on the angled surface of the swash plate which at this point in the cycle of rotation is extending away from the cylinder block. As the bore passes out of alignment with the inlet port the open end thereof is closed off with a quantity of water in it.

As the cylinder block continues to rotate each slipper passes up the angled surface of the swash plate which is now extending towards the cylinder block. This has the effect of causing the piston connected to the slipper to be driven back down the bore in which it is located, compressing the volume of water contained therein. When the bore passes into alignment with the outlet port in the port plate the water in the bore is expelled therethrough under pressure. In this way water entering the pump under relatively low pressure is pumped out at high pressure.

The water pump described hereinabove can also function as an hydraulic motor. In this regard, the pump is simply operated in reverse; water under high pressure is applied to the inlet port which has the effect of driving each of the pistons in turn down its respective bore. As the slipper connected to the end of each piston passes over the angled surface of the swash plate it has the effect of causing the cylinder block and the drive shaft connected to it to turn.

It is essential to the effective operation of the hydraulic pump that an effective, low friction contact is maintained between the facing surfaces of the slippers and the angled swash plate. In slippers of conventional design a circular polymer slipper pad is secured to the front face of the slipper, conveniently by means of a grub screw, or is moulded onto the front face of the slipper. The front

surface of the slipper pad defines a centrally located recess or pocket and into the centre of this recess a capillary sized through bore opens. The through bore extends from the recessed surface of the slipper pad, through the slipper and the ball shaped foot on which it is mounted, and connects with the hollow section of the piston. In this way liquid is supplied from the cylinder bore in which a piston assembly is mounted through to the front surface of the slipper pad associated with that piston assembly. The liquid in the recess of the slipper pad serves to create a hydrostatic bearing between the slipper pad and the angled swash plate against which it is supported when the hydraulic pump/motor is in use. This hydrostatic bearing causes the slipper pad to lift off the swash plate into a hydrostatically balanced condition as each piston assembly sees pressure. Of course, the film of liquid in the recess of each slipper pad also serves to lubricate and allow free movement of the slipper pad over the surface of the angled swash plate.

Unfortunately, the circular polymer slipper pad of conventional slipper designs is not very tolerant of the pressure changes which take place across its surface as a result of the pressure changes which are inherent in an axial piston pump/motor. In this regard, because the slipper pad covers substantially all of the front face of the slipper it is subject to considerable bending moments and these can lead to premature failure due to fatigue stresses. Furthermore, where the slipper pad is held in place on the slipper by mechanical fixing means, e.g. a countersunk screw, this has the effect of reducing the overall piston ball seat area

- the end of the screw must be accommodated in the area of the piston ball seat. This reduces the load taking area and results in increased piston ball seat stresses.

It is an object of the present invention to provide a slipper design for a piston assembly intended for use in an hydraulic pump or motor in which the problems associated with conventional slippers as outlined hereinabove are obviated or at least substantially mitigated.

According to the present invention there is provided a piston assembly for an axial displacement pump or motor comprising a piston having at one end a ball shaped piston foot and a slipper, the rear end of which defines a piston ball seat in which the ball shaped piston foot is received, and a slipper pad which defines an annular, centrally located recess or pocket at the front end of the slipper, characterised in that the slipper pad comprises an annular ring of polymer material.

In one embodiment of the present invention the slipper defines a planar front face in which is provided an annular groove and the annular ring, the axial length of which is greater than the depth of the annular groove, is mounted in the annular groove.

The use of a polymer ring pad in place of a conventional circular slipper pad (whether mechanically fixed to the slipper or over moulded onto it) greatly reduces production costs. Furthermore, the polymer ring pad is much stronger than a conventional circular slipper pad for an equivalent space envelope.

With the polymer ring pad there is no need for a central screw to hold the

pad in place, nor is there any need for a polymer feed hole in the slipper through which polymer can be fed to the front surface of the slipper during over moulding of the pad. The advantage of this that a much larger piston ball seat area is provided between the ball shaped piston foot and the slipper - only the capillary sized bore hole needs to be accommodated through the slipper seat. This gives a much increased load bearing area and as a consequence reduces the piston ball seat stresses.

Yet another advantage of the polymer ring pad is that the slipper itself can be much thicker at the centre than is the case with conventional designs where a recess must be provided in the slipper to accommodate the circular slipper pad. It will be apparent that this increased thickness gives the slipper a much more rigid construction and reduces the likelihood of bending at the piston ball to piston ball seat interface.

The slipper design in accordance with the present invention allows for much improved load carry capacity over conventional slipper designs with the result that the working life of a hydraulic pump/motor can be extended for existing typical working loads or pressures.

In another embodiment a piston assembly according to claim 1 characterised in that the slipper comprises a metal annular ring, the inner diameter of which is substantially equal to the outer diameter of the polymer annular ring pad, and the axial length of which is less than that of the polymer annular ring pad, wherein the polymer annular ring pad is received co-axially within the metal

annular ring, such that the hoop stresses in the polymer annular ring pad are constrained by the metal annular ring.

In this slipper and pad design a significant part of the slipper to piston load is eliminated by using the working fluid column in the slipper, that is to say the fluid constrained within the inner polymer ring to support much more of the piston load.

Furthermore, by dispensing with that part of the slipper which in a conventional slipper is required to support the slipper pad, the mass of the slipper is greatly reduced and therefore the inertia of the slipper is less critical at high rotational speeds.

In addition, because the slipper is essentially defined by a ring of polymer, the slipper to swash plate load is decreased, thereby reducing the surface stresses in the slipper ring to swash plate interface. This results in lower friction, giving improved starting performance and reduced slipper ring wear.

Finally, since this construction allows a relatively large ball on the piston (typically larger than the piston bore whereas a conventional construction would have a ball smaller than the piston bore) ball stresses and thus wear are reduced.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows a cross-sectional view through an axial displacement water pump/motor comprising conventional slippers;

Fig. 2 shows a cross sectional view of a slipper for use with a piston in the

water pump/motor shown in Fig. 1 according to a first embodiment of the present invention; and,

Fig. 3 shows a cross sectional view of another slipper for use with a piston in the water pump/motor shown in Fig. 1 according to a second embodiment of the present invention.

Referring to Fig. 1 of the accompanying drawings the water pump/motor comprises cylindrical outer casing 1 which is closed at one end by a port end covering 2 and at the opposite end by a mounting flange plate or snout 3. Bolts (not shown) hold the port end covering 2 and the snout 3 to the outer casing 1 and O-rings 4 seal the joints therebetween and prevent any leakage of liquid.

An aperture is provided in the centre of the snout 3 within which is mounted a drive shaft 5. The drive shaft 5 is held in place by means of a seal housing 6 which is recessed into the front face of the snout 3 and held in place by means of socket head capscrews 7 (only one of which is shown for ease of illustration). An O-ring 8 between the seal housing 6 and the snout 3 prevents liquid from leaking therebetween. The seal housing 6 also supports a seal 9 which prevents liquid from leaking past the drive shaft 5. The drive shaft 5 is rotatably supported within the aperture in the snout 3 by means of front and rear bearings 10 and 11.

Keyed to the inner end of the drive shaft 5 is a dummy shaft 11 and keyed onto the dummy shaft 11 is a cylinder block 12. The cylinder block is rotatable with the drive shaft 5 within the cavity defined by the outer casing 1, the port end

covering 2 and the snout 3. A snout bush 13 allows free rotation of the cylinder block 12 on the inner end of the snout 3.

The cylinder block 12 carries a plurality of piston assemblies 14 (only two of which are actually shown for ease of illustration). Each of the piston assemblies 14 is mounted within a respective axially extending piston bore in the cylinder block 12 and is axially slidable back and forth therein. Each of the piston assemblies 14 comprises a piston 15 having a hollow body and a ball shaped piston foot 16 at one end on which is mounted a slipper 17. The slippers 17 are supported against and are slidable over the surface of an angled swash plate 30 secured to the inner face of the snout 3.

Each slipper 17 is held in place on the ball shaped piston foot 16 by a retaining cap of the type commonly referred to as a "top hat", and a split ring retaining bush. A circular slipper pad 20 is secured to the front surface of the slipper by means of a countersunk screw. A piston ball seat supports the slipper on the ball shaped piston foot. Finally, a frictionless sleeve around the body of the piston 15 ensures free movement of the piston assembly 14 back and forth within its respective piston bore.

In order to provide a hydrostatic bearing between the front surface of each slipper pad 20 and the swash plate 30, a capillary sized bore 23 is provided from the front surface of the slipper pad 20 through to the hollow body of the piston 15. As shown, this capillary sized bore 23 passes through the screw which secures the slipper pad 20 to the slipper 17.

As an alternative to securing the slipper pad 20 to the slipper 17 by means of a screw, the slipper pad 20 may be over moulded onto the slipper 17. In this case a through hole must be provided from the piston seat to the front surface of the slipper through which the polymer can flow during moulding. In addition, the capillary sized through bore must be maintained in this hole.

As discussed hereinbefore the conventional slipper used in the axial displacement pump/motor shown in Fig. 1 suffers from several disadvantages. The slipper pads in accordance with the first and second aspects of the present invention will now be described.

Referring to Fig. 2 there is shown a slipper 41 having a piston ball seat 42 mounted in a cavity in the rear surface thereof which facilitates connection of the slipper to the ball shaped piston foot of a piston (not shown). The front surface of the slipper is planar except for a circumferential groove 43 machined in it. In this groove 3 there is mounted a ring shaped slipper pad 44 comprised of a polymer material. The ring shaped slipper pad 44 is retained in the groove 43 by a friction fit. The depth of the circumferential groove 43 is such that the ring shaped slipper pad 44 stands proud of the planar surface of the slipper 41 itself. It is, of course the ring shaped slipper pad 44 which engages with the surface of the swash plate in an axial displacement pump or motor. Finally a capillary sized through bore 45 is provided in the slipper 41 from the front face thereof through to the piston ball seat 42.

By replacing the conventional circular slipper pad with a ring shaped

slipper pad a slipper design which is very tolerant to the pressure changes which occur in an axial displacement hydraulic motor/pump is obtain. The conventional circular slipper pad is subject to considerable bending forces by virtue of the fact that it covers substantially all of the front surface of the slipper. Premature failure due to fatigue stresses is therefore relatively common. This problem is not as great with the ring shaped slipper pad.

Furthermore with the ring shaped slipper pad there is no need for a securing screw or connecting shaft of polymer between the slipper pad and piston ball seat as there is with conventional circular slipper pads. This means that the piston ball seat area is greatly increased, thereby increasing the load taking area and reducing piston ball seat stresses.

Finally, because the slipper does not have a large hole at the centre to accommodate the screw or the shaft of polymer which are required to secure conventional circular slipper pads in place, it is much thicker at the centre than a conventional slipper. This gives it a much more rigid construction, reducing bending of the piston ball seat to piston ball interface and repetitive stress cycles due to metal deformation.

Referring now to Fig. 3 there is shown a slipper which consists of an inner ring of polymer 51 and an outer ring of metal 52. The inner ring 51 is of slightly greater length axially than the outer ring 52 such that it defines a ring shaped slipper pad 53 at one end. In use, this ring shaped slipper pad 53 is supported against a swash plate. At the opposite end of the inner ring 51 from the ring

shaped slipper pad 53 the inner surface of the inner ring is shaped to define a piston ball seat 54. The ball shaped piston foot of a piston is received within the inner ring 51 against the ball seat 54.

The outer ring 52 of metal is provided to constrain hoop stresses in the inner ring 51.

In this slipper design that part of the slipper which would have supported the circular slipper pad is dispensed with. Instead, the ring shaped slipper pad is supported directly on the ball shaped piston foot. This design reduces the mass of the slipper and therefore inertia is much less of a problem at high rotational speeds.

Leakage between the piston ball and piston ball seat is minimised by manufacturing the inner ring from a polymer which is deformable, at least in the region of the piston ball seat.

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CLAIMS

1. A piston assembly for an axial displacement pump or motor comprising a piston (15) having at one end a ball shaped piston foot (16) and a slipper (41), the rear end of which defines a piston ball seat (42) in which the ball shaped piston foot (16) is received, and a slipper pad (44) which defines an annular, centrally located recess or pocket at the front end of the slipper (41), characterised in that the slipper pad (44) comprises an annular ring (44) of polymer material.

2. A piston assembly according to claim 1, characterised in that the slipper (41) defines a planar front face in which is provided an annular groove (43) and the annular ring (44), the axial length of which is greater than the depth of the annular groove (43), is mounted in the annular groove (43).

3. A piston assembly according to claim 2 characterised in that the annular ring (44) retained in the annular groove (43) by a friction fit.

4. A piston assembly according to claims 2 or 3, characterised in that a cylindrical cavity is provided in the rear end of the slipper (41), in which is received a piston ball seat (42).

5. A piston assembly according to claim 1 characterised in that the slipper comprises a metal annular ring (52), the inner diameter of which is substantially equal to the outer diameter of the polymer annular ring pad (53), and the axial length of which is less than that of the polymer annular ring pad (53),

wherein the polymer annular ring pad (53) is received co-axially within the metal annular ring (52), such that the hoop stresses in the polymer annular ring pad (53) are constrained by the metal annular ring.

6. A piston assembly according to claim 5 characterised in that the rear end of the polymer annular ring pad (53) defines a piston ball seat (54).

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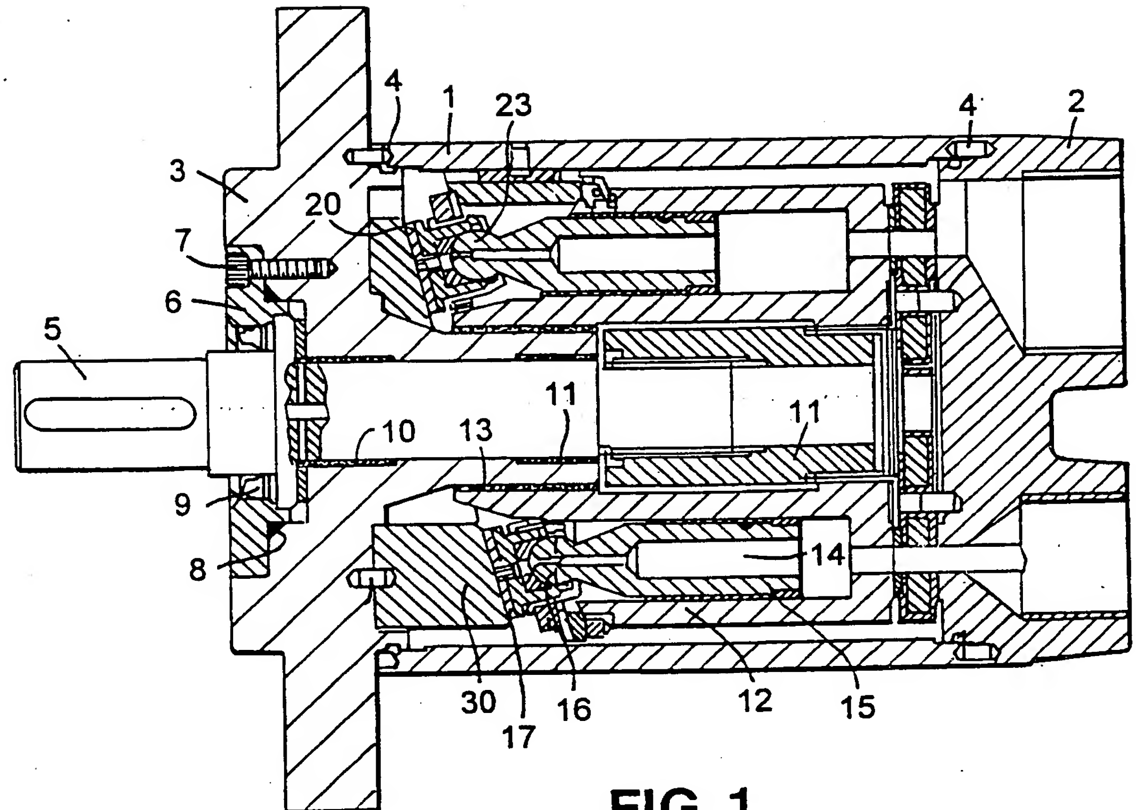

FIG. 1

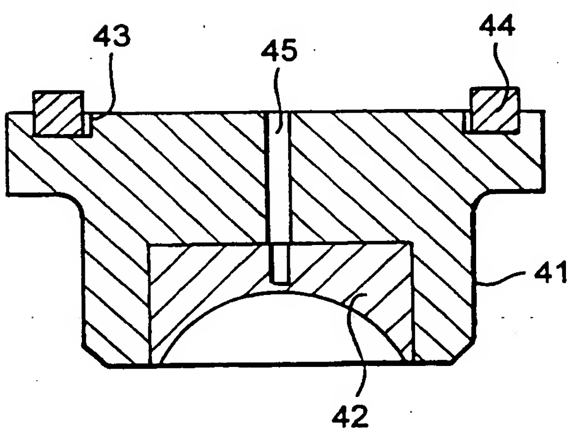

FIG. 2

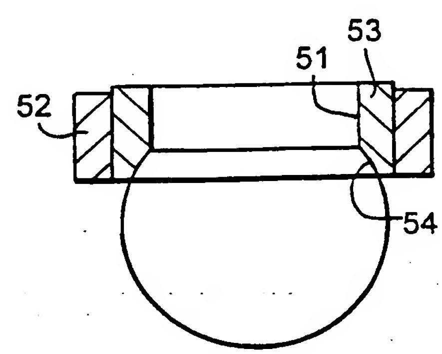

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/00655

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F04B1/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F04B F01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 29 09 248 A (VOITH GETRIEBE KG) 11 September 1980 see page 4 - page 8; figure 1 ---	1,2
Y	GB 1 141 605 A (DOWTY TECHNICAL DEVELOPMENTS) 29 January 1969 see page 1, line 123 - page 2, line 13; figure 4 ---	1,2
A	DE 43 01 123 A (DANFOSS A S NORDBORG) 21 July 1994 see column 2, line 53 - column 3, line 2 see column 5, line 40 - column 6, line 28 ---	1-6
A	US 5 601 009 A (JEPSEN HARDY P ET AL) 11 February 1997 see column 2, line 10 - column 3, line 7 --- -/--	1-3

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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16 June 1998	22/06/1998

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter. onal Application No
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